Annual dynamics of bivalve populations in muddy bottoms of the Ensenada de Baiona (Galicia, NW Iberian Peninsula)

Dinámica anual de las poblaciones de bivalvos de los fondos fangosos de la Ensenada de Baiona (Galicia, NO Península Ibérica)

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ABSTRACT

The bivalves *Abra nitida, Loripes lacteus* and *Thyasira flexuosa* are common inhabitants of muddy sediments in the Galician rías (NW Spain). Abundance, recruitment and growth of these species were studied from May 1996 to May 1997 in the Ensenada de Baiona, a small inlet in the Ría de Vigo, Galicia, NW Spain. Specimens were collected in a shallow subtidal site with muddy sediments. Growth and life span were estimated from length-frequency data by means of statistical packages based on von Bertalanffy's equation. The studied populations showed marked seasonal variations in numbers with only one period of recruitment. *Thyasira flexuosa* showed greater maximal abundances than in other Galician rías, apart from the Ría de Coruña. The population of *L. lacteus* was mainly composed of small individuals and the longevity of *A. nitida* was greater than in other areas.

RESUMEN

Los bivalvos *Abra nitida, Loripes lacteus* y *Thyasira flexuosa* son especies comunes en fondos fangosos de las rías gallegas (Noroeste de España). La dinámica anual, reclutamiento y crecimiento de estas especies fue estudiado desde Mayo de 1996 a Mayo de 1997 en la Ensenada de Baiona (Ría de Vigo). Los ejemplares estudiados fueron recolectados en un fondo fangoso a 2 m de profundidad. El crecimiento y longevidad fueron estimados a partir de datos de frequencia de tallas por medio de paquetes estadísticos basados en el modelo de crecimiento y ecuación de von Bertalanffy. Las poblaciones estudiadas mostraron unas marcadas variaciones estacionales en número de individuos y un único período de reclutamiento anual. Las máximas densidades de *T. flexuosa* fueron mayores que las registradas en la mayoría de las rías gallegas, salvo en la Ría de Coruña. La población de *L. lacteus* estuvo compuesta principalmente por individuos juveniles mientras que la longevidad de *A. nitida* fue mayor que en otras áreas.

KEY WORDS: bivalves, soft bottoms, dynamics, growth, Ensenada de Baiona, rías, Atlantic Ocean.
PALABRAS CLAVE: bivalvos, fondos blandos, dinámica, crecimiento, Ensenada de Baiona, rías, Océano Atlántico.

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INTRODUCTION

Marine benthic assemblages in shallow subtidal soft-bottoms are frequently composed of a large number of species, some of which may show fluctuations of their populations through time (Rees, 1983). The distribution and temporal dynamics of soft-bottom faunas may be conditioned by a number of abiotic factors and biotic interactions (Rhoads and Young, 1970; Gray, 1981). Variations of these factors at different spatial and temporal scales may translate into variations in density of species and composition of assemblages. The study of these patterns of variation is therefore crucial when determining conditions and quality of marine benthos and for management of biodiversity and natural resources (Kelaher and Cole, 2005).

The Galician rías are a complex and unique kind of estuarine systems with high primary productivity (Tenore *et al.*, 1995) and great economic and social importance because of the presence of fisheries and diverse shellfish resources (Figueiras, Labarta and Fernández, 2002). In addition, the rías have a large variety of sediments inhabited by a diverse benthic fauna (Cadée, 1968; López-Jamar and Mejuto, 1985; Garmendia, Sánchez-Mata and Mora, 1998). In some rías, a number of human activities, such as the culture of bivalves on rafts, the construction of harbour facilities and the disposal of sewage, have already induced large alterations in composition of benthic assemblages through organic enrichment and changes in sedimentary composition (López-Jamar, 1978; López-Jamar and Mejuto, 1985). These disturbances may also affect the variability of individual populations of benthic organisms (Underwood, 1992). Therefore, in order to identify the impact of anthropogenic disturbances on the marine benthos it is necessary to study the distribution and natural spatio-temporal variations of the benthic infauna.

Despite the existing wealth of information on the soft-bottom fauna of many Galician "rías", little is known of the distribution and dynamics of the subtidal soft-bottom fauna from the Ensenada de Baiona (Anadón, 1980). This inlet is located at the mouth of the Ría de Vigo and its soft bottoms are mostly sandy (Alejo, Austin, Francés and Vilas, 1999; Moreira, Quintas and Troncoso, 2005). Over the last 30 years, a deposition of large amounts of silt/clay has been detected in the shallow sediments around the harbour of Baiona due to the change in dynamics of local currents after the construction of a jetty in the 1970s (Alejo and Vilas, 1987). An "*Abra alba* community" is present in these muddy sediments and is dominated by several species of polychaetes and bivalves (Moreira *et al.*, 2005, 2006). Among them, the bivalves *Abra nitida* (Müller, 1776), *Loripes lacteus* (Linnaeus, 1758) and *Thyasira flexuosa* (Montagu, 1803) are numerically dominant species (Moreira *et al.*, 2005). Bivalves are a key component of the structure of soft-bottom benthic assemblages (Peterson and Andre, 1980; Widdicombe and Austen, 1999), the diet of a number of demersal fish of economic interest (Dauvin, 1985; Brey, Arntz, Pauly and Rumohr, 1990) and may serve as indicators of the conditions of marine bottoms (Stirling, 1975; Bresler, Bissinger, Abelson, Dizer, Sturm, Kratke, Fishelson and Hansen, 1999).

This study describes the temporal dynamics of the aforementioned dominant bivalves during a one-year period from a muddy site in the harbour of Baiona. For instance, *T. flexuosa* is known to be a dominant species when recolonizing muddy sediments and thus it can be expected to have a higher growth rate when compared to other bivalves. Growth and longevity were also estimated for those species and compared with those of other populations. This work is part of a larger baseline study on the benthic assemblages in subtidal soft sediments of the Ensenada de Baiona.

MATERIAL AND METHODS

Sampling and laboratory procedures: The studied site (42° 07′ 19″ N, 8° 50′ 45″ W) was selected as being representative of the "*Abra alba* community" present in the muddy sediments of the Ensenada de Baiona. The site is at a depth of 2 m and the sediment is mostly muddy (> 50% silt/clay). Five replicate samples were collected by means of a Van Veen grab (0.056 m^2) at monthly intervals between May 1996 to May 1997. This grab penetrates about 15 cm into the sediment. Total sampled area (0.28 m^2) was larger than that of other works devoted to the same bivalve species studied here (e.g., 0.175 m^2 for *Thyasira flexuosa* in LÓPEZ-JAMAR, GONZÁLEZ AND MEJUTO, 1987; 0.175 m^2 for *Abra nitida* in FRANCESCH AND LÓPEZ-JAMAR, 1991; 0.20 m^2 for *Loripes lacteus* in CURRÁS AND MORA, 1996). Samples were sieved through a 0.5 mm mesh and fixed in 4% formaldehyde. Molluscs were sorted from the sediment and counted. The length of the anterior-posterior axis of the shell was measured to the nearest 0.1 mm with vernier caliper for the larger specimens and with an eyepiece micrometer for the smaller. Sediment samples were taken monthly to measure particle size composition, carbonates and total organic matter. Median grain size (Q_{50}) and sort coefficient (S_o) were also determined for each sample. Content of carbonates (%) was estimated by a treatment of the sample with hydrochloric acid. Content of total organic matter (%) was estimated from the weight loss on combustion at 450°C for 4 hours. Analyses of correlation through Spearman coefficient were done to assess the relationships between the densities of the bivalves and the environmental variables.

Population parameters: For estimates of growth parameters, the analysis of the length-frequency distribution method was used, through the routine ELEFAN I (Electronic Length Frequency Analysis; PAULY, 1987) from the program FISAT (FAO-ICLARM Stock Assessment Tools; GAYANILO, SPARRE AND PAULY, 1996), that assumes a von Bertalanffy equation for general growth, modified for seasonality (PAULY AND GASCHÜTZ, 1979). Although various models have been proposed for the description of individual body-growth (RICHARDS, 1959; PAULY, 1980; SCHNUTE, 1981), the VON BERTALANFFY model (1938) has been the most widely used for invertebrates and fishes (LUCKHURST, DEAN AND REICHERT, 2000; LAUDIEN, BREY AND ARNTZ, 2003). The von Bertalanffy equation was therefore used for this work [$L_t = L_\infty \{1\text{-}e^{[-K(t-to) + (CK/2\pi)\,sen\,(2\pi (t-ts))]}\}$], where L_t is length (mm) at time t, L_∞ is the maximal theoretic length that the species would reach if it lived indefinitely, K is the intrinsic growth rate (curvature parameter), C is a constant for the amplitude of oscillation in seasonal growth, t_o is age at zero length, and t_s is the initial point of seasonal oscillation in relation to t = 0. The graphical representation of this equation produces a curve that is evaluated through the goodness-of-fit index Rn (GAYANILO *ET AL.*, 1996). The growth index (= phi-prime index, ϕ') was used to measure the growth performance of the species (PAULY AND MUNRO, 1984). This index identifies the distorted estimates of the growth parameters because there is a recognized trend of the ELEFAN routine to underestimate K and overestimate L_∞ (ISAAC, 1990). Winter point (WP) is also provided, i.e. the point of lowest growth in the year, expressed as a decimal fraction of the year.

RESULTS

Environmental parameters: Sediment was mainly composed of silt/clay (< 0.063 mm; 75.2 ± 4.6%, mean ± SD) and very fine sand (0.125-0.063 mm; 17.0 ± 2.7%). Median grain size ranged from 0.031 mm to 0.040 mm with an annual mean of 0.035 ± 0.003 mm. Selection of the sediment ranged from moderate to poor. Content of total organic matter was high (10.0 ± 1.7%) and content of carbonates was low (8.7 ± 0.9%). Temperature of water near to the sediment ranged from

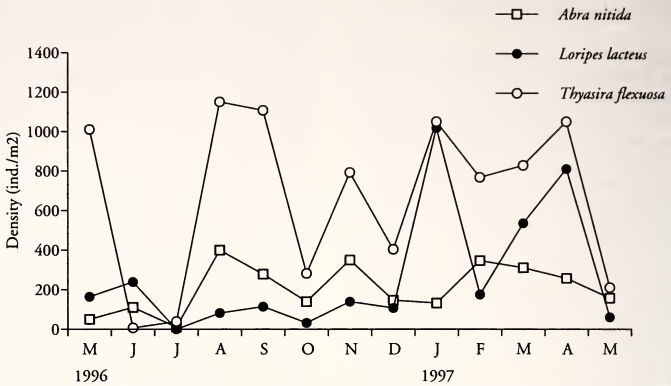

Figure 1. Monthly variations in density (ind. m^{-2}) of *Abra nitida*, *Loripes lacteus* and *Thyasira flexuosa* at the study site in the Ensenada de Baiona.

Figura 1. Variaciones mensuales de la densidad (ind. m^{-2}) de Abra nitida, Loripes lacteus *y* Thyasira flexuosa *en el fondo estudiado en la Ensenada de Baiona.*

11.0°C in January to 19.5°C in August with an annual mean of 15.5 ± 2.65°C. Salinity showed an annual mean of 33.6 ± 1.8‰ with minimal value in December (30.0‰) and maximal in July (35.3‰).

Population abundance: Densities of *Abra nitida* varied from 11 to 400 individuals m^{-2}, with a monthly mean of 207 ± 124 ind. m^{-2} (± SE). The greater abundances were recorded in August-September, November and February-March while the smallest numbers were found from May to July 1996 (Fig. 1). Recruitment occurred once a year in summer according to the larger number of juveniles (< 4 mm) found in samples from August (Fig. 2). Large individuals, 16 to 18 mm in length, comprised less than 3% of the population.

Numbers of *Loripes lacteus* fluctuated between 0 and 1018 ind. m^{-2}, with a monthly mean of 268 ± 319 ind. m^{-2}. This species showed small variations in density between late spring and autumn with a strong increase in numbers during winter-early spring (Fig. 1) due to recruitment of juveniles (< 4 mm; Fig. 2). The population was mainly composed of small animals (< 5 mm, > 75%) throughout the study. Large animals (> 10 mm) were scarcely found through the year (< 6%).

Densities of *Thyasira flexuosa* were extremely variable (Fig. 1), oscillating between 7 and 1150 ind. m^{-2} with a monthly mean of 669 ± 423 ind. m^{-2}. The highest numbers were recorded in August-September and January-April. In June-July this species was almost absent from samples. Recruitment occurred once a year during spring with the largest numbers of small individuals (< 2 mm) found in April 1997 (Fig. 2). A large proportion of the population consisted of animals between 3 and 6 mm (80%) while large animals (7 to 9 mm) were scarce (4%).

Numbers of *T. flexuosa* and *L. lacteus* were positively correlated with total content of sand ($p < 0.05$) while density of *A. nitida* was positively correlated with content of very fine sand ($p < 0.05$). *L. lacteus* was negatively correlated with content of silt/clay ($p < 0.05$).

Growth and life span: Table I shows the growth parameters of von Bertalanffy's curve for the three studied species. *Loripes lacteus* shows the better performance, reaching a larger body

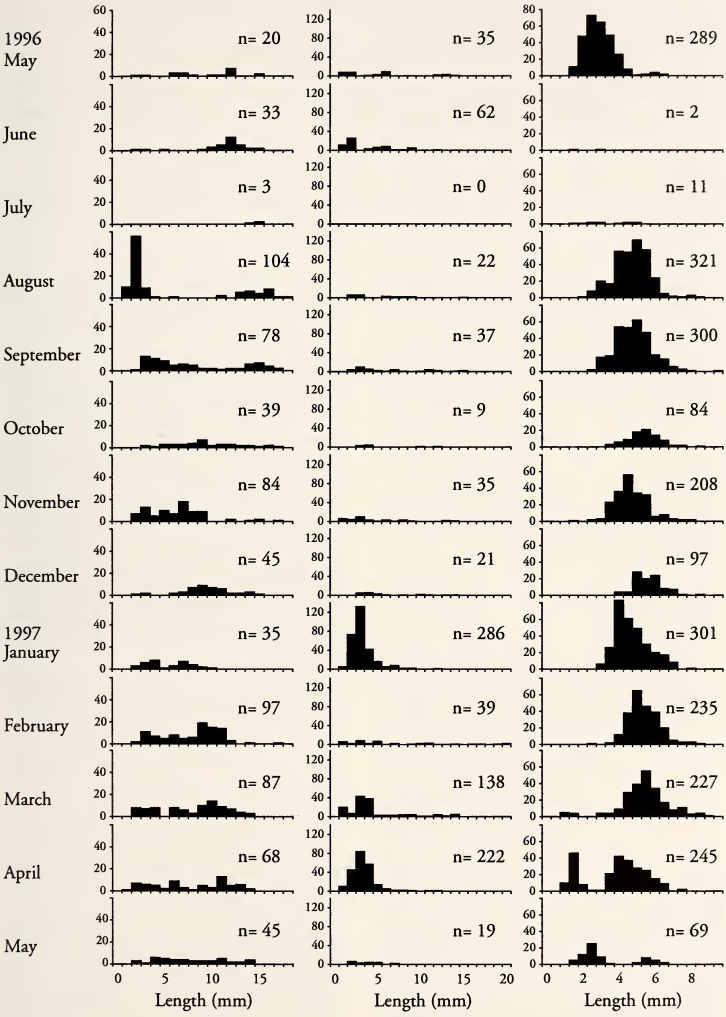

Figure 2. Length-frequency distribution of bivalves at the study site in the Ensenada de Baiona. A, *Abra nitida*; B, *Loripes lacteus*; C, *Thyasira flexuosa*. Number of individuals measured (n) are given for each sampling date.

Figura 2. Distribución de frecuencias de tallas de bivalvos en el fondo estudiado en la Ensenada de Baiona. A, Abra nitida; B, Loripes lacteus; C, Thyasira flexuosa. *Se indica el número de individuos medidos (n) en cada fecha de muestreo.*

Table I. Growth, mortality and life span estimates for *Abra nitida*, *Loripes lacteus* and *Thyasira flexuosa* at the study site in the Ensenada de Baiona.
Tabla I. Crecimiento, estimas de mortalidad y longevidad para Abra nitida, Loripes lacteus *y* Thyasira flexuosa *en el fondo estudiado de la Ensenada de Baiona.*

	L_∞ (mm)	K (year^{-1})	C	WP	Rn	ϕ'	L_{max} (mm)	t_{max} (years)
A. nitida	19.5	0.26	0.1	0.2	0.154	2.0	17.5	8.8
L. lacteus	21.9	0.31	0.3	0.4	0.150	2.2	20.0	4.9
T. flexuosa	12.9	0.40	0.1	0.2	0.156	1.8	9.3	3.2

size in less time than the other species, as indicated by the values of f'. Estimates of growth indicated small seasonal oscillations (0.1-0.3) for the three species. The calculated WP indicated a decreased growth rate in late winter for *Abra nitida* and *Thyasira flexuosa* (WP = 0.2 x 12 = 2.4, February-March) and in spring for *L. lacteus* (WP = 0.4 x 12 = 4.8, April-May). The estimated life span (t_{max}) was higher for *A. nitida* than for *L. lacteus* and *T. flexuosa* (8.8 years vs 4.9 and 3.2 years, respectively).

DISCUSSION

Abra nitida

Abra nitida has typically been recorded from muddy bottoms (Glemarec, 1964; Mora, 1982). This species acts primarily as a deposit-feeder (Wikander, 1980) and contributes to the reworking of sediment through locomotion and feeding (Rhoads and Young, 1970). Monthly densities in the Ensenada de Baiona were similar to those found by Francesch and López-Jamar (1991) in muddy bottoms from the Ría de Coruña (46-480 ind. m^{-2}). In our study, maximal densities were recorded in late summer-autumn and early spring while in other areas maximal densities occured during spring-summer (Josefson, 1982; Francesch and López-Jamar, 1991; López-Jamar, Francesch, Dorrío and Parra, 1995). Because of the high variability in numbers of its populations, *A. nitida* has been considered as a volatile and opportunistic species, which may show great increases in densities followed by dramatic declines (Buchanan, Kingston and Sheader, 1974; Josefson, 1982).

In the Ría de Coruña, recruitment begins in October and ends in May with peaks in January-February (Francesch and López-Jamar, 1991) while in the Ensenada de Baiona it occurs in late summer. Josefson (1982) points out that recruitment may occur from late summer to autumn although the actual periods may be variable. Furthermore, success of recruitment may depend on the size of adult populations and those of other competitors, such as deposit-feeding polychaetes, which may ingest new spat or compete for food (Josefson, 1981, 1982).

Data on the growth of *Abra nitida* from other areas are scarce (Josefson, 1982; Francesch and López-Jamar, 1991). In the Ensenada de Baiona, life span and maximal length were greater than those found in the Ría de Coruña in similar bottoms (8.77 years and 17.5 mm vs 3.9 years and 14.3 mm, respectively). Longevity in established adult populations of *A. nitida* may be conditioned by predation of boring gastropods such as naticids (Josefson, 1982) and therefore longevity may be greater in the absence of strong predation. For soft sediments deeper than those studied at the Ensenada de Baiona, Josefson (1982) recorded growth rates of 10 mm for 1 to 1.5 years after recruitment. Growth may, however, vary between years and sites at different depths from year to year and is strongly dependent on intraspecific competition for food when there are

large populations of adults (JOSEFSON, 1982). Thus, differences in growth rates between populations may be the result of differences in the size-structure of these populations.

Loripes lacteus

Loripes lacteus is a common bivalve in fine sand, muddy sand and mud and can also be found in polluted sediments (CADÉE, 1968; GUERRA-GARCÍA, CORZO AND GARCÍA-GÓMEZ, 2003). This species may inhabit reduced sediments and harbours chemoautotrophic sulphur-oxidizing bacteria within its gills (JOHNSON AND FERNANDEZ, 2001). In the Galician "rías", *L. lacteus* is a characteristic species from soft sediments colonized by seagrasses such as *Zostera marina* L. and *Z. noltii* Hornem. (CURRÁS AND MORA, 1996; OLABARRÍA, URGORRI AND TRONCOSO, 1998). However, in the Ensenada de Baiona, *L. lacteus* has only been found in muddy sediments (MOREIRA *ET AL.*, 2005).

The population studied in the Ensenada de Baiona was mainly composed of juvenile animals. CURRÁS AND MORA (1996) recorded differences in size-class structure between sediments of different granulometry. Thus, larger animals found in sandy mud with *Zostera noltii* throughout the year measured between 7 and 11 mm, while populations in muddy sand with *Zostera marina* were dominated by animals smaller than 5 mm (CURRÁS AND MORA, 1996). The scarce presence of adults in the muddy sediments studied here might, however, be due to migration of adults to other sediments. Furthermore, GUERRA-GARCÍA *ET AL.* (2003) point out that larger individuals of *Loripes lacteus* in similar sediments tend to appear deeper into the sediment (> 10 cm depth) and therefore these animals could only be sampled more accurately with devices that penetrate deeper into the sediment.

Loripes lacteus may recruit twice a year, in late winter-spring and summer-autumn (MASSÉ AND GUERIN, 1978; CURRÁS AND MORA, 1996; JOHNSON, FERNANDEZ AND PERGENT, 2002). Here, the largest numbers of juveniles were recorded between January and April. No recruitment was detected during summer and autumn. CURRÁS AND MORA (1996) suggest that macroalgal growth on the surface of sediment during summer may prevent successful recruitment. Macroalgal blooms are known to affect the physico-chemical features of the sediment-water interface and the underlying sediments and therefore affect the infauna (RAFFAELLI, RAVEN AND POOLE, 1998), although these effects may differ between taxa (LOPES, PARDAL AND MARQUES, 2000). In our case, the presence of ulvacean algae during July (personal observation) could have had a negative effect on summer recruitment of *L. lacteus*, hence the small numbers of juveniles during the following months.

Thyasira flexuosa

In the Galician rías, *Thyasira flexuosa* is a common species in muddy sediments with a high content of organic matter (LÓPEZ-JAMAR AND MEJUTO, 1985; LÓPEZ-JAMAR AND PARRA, 1997; OLABARRÍA *ET AL.*, 1998) and can be the numerically dominant bivalve (LÓPEZ-JAMAR *ET AL.*, 1987; LÓPEZ-JAMAR AND PARRA, 1997). This species is also present in sandy bottoms although in smaller numbers (LÓPEZ-JAMAR *ET AL.*, 1995; LÓPEZ-JAMAR AND PARRA, 1997). *T. flexuosa* may show large increases in numbers after events such as oil spills and other anthropogenic disturbances occurring in harbour areas when they are followed by periods of recruitment (DAUVIN, 1982; LÓPEZ-JAMAR *ET AL.*, 1987; LÓPEZ-JAMAR AND MEJUTO, 1988). In the Ensenada de Baiona, the distribution of this bivalve was restricted to muddy sediments (MOREIRA *ET AL.*, 2005). Here, maximal densities were larger than in other muddy sediments with high organic content from other Galician rías, except the Ría de Coruña (LÓPEZ-JAMAR AND PARRA, 1997). LÓPEZ-JAMAR AND PARRA (1997) suggest that the greater mean densities in the Ría de Coruña in comparison to other rias may be due to the greater water content of sediment in the latter. Therefore, muddy

sediments of greater fluidity and less stable than those present in the Ría de Coruña would be less favourable for *T. flexuosa* (López-Jamar and Parra, 1997). In our study, numbers of *T. flexuosa* showed a positive correlation with content of sand although sediment was mainly composed of silt/clay throughout the year. Thus, the presence of sand, even in small amounts, may improve the stability of sediments and therefore favour the presence of *T. flexuosa*.

In the Ría de Coruña, *Thyasira flexuosa* spawns in January and February and recruits during spring (López-Jamar *et al.*, 1987), with peaks between April and May (López-Jamar and Mejuto, 1988). Juveniles between 0.7 and 1.3 mm appear by the end of winter with peaks of abundance in May and June (López-Jamar and Parra, 1997). The same situation has been observed for the population in the Ensenada de Baiona, which also showed only one period of recruitment during the year. Ibanez and Dauvin (1988) recorded peaks of abundance in autumn for muddy sands in the Bay of Morlaix, although these may also occur in spring and summer.

Growth parameters estimated from the population in the Ensenada de Baiona were similar to those found by López-Jamar *et al.* (1987) from the Ría de Coruña although growth rate and life span were slightly greater in our study (K, 0.4 vs 0.28-0.37; t_{max}, 3.2 vs 3 years). This suggests that *Thyasira flexuosa* may show greater growth rates during recolonization of disturbed sediments coincident with periods of recruitment (López-Jamar *et al.*, 1987). Posterior interannual variations in growth of these populations may be the result of intraspecific competition following great increase in numbers (López-Jamar *et al.*, 1987).

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